

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
 US Department of Commerce
 United States Patent and Trademark
 Office, PCT
 2011 South Clark Place Room
 CP2/5C24
 Arlington, VA 22202
 ETATS-UNIS D'AMERIQUE
 in its capacity as elected Office

| | |
|-----------------------------------------------------------------------|-----------------------------------------------------------|
| Date of mailing (day/month/year) 06 March 2001 (06.03.01) | |
| International application No. PCT/SE00/01376 | Applicant's or agent's file reference 2001521 |
| International filing date (day/month/year) 29 June 2000 (29.06.00) | Priority date (day/month/year) 09 July 1999 (09.07.99) |
| Applicant HEYDEN, Anders | |

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
 17 January 2001 (17.01.01)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

| | |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35 | Authorized officer R. E. Stoffel Telephone No.: (41-22) 338.83.38 |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|

REC'D 04 DEC 2001

WIPO

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| | | |
|--------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Applicant's or agent's file reference 2001521 | FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) | |
| International application No. PCT/SE00/01376 | International filing date (day/month/year) 29.06.2000 | Priority date (day/month/year) 09.07.1999 |
| International Patent Classification (IPC) or national classification and IPC ₇ G02B 21/00, G02B 21/36, G06T 5/00 | | |
| Applicant CELLAVISION AB ET AL. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

| | |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Date of submission of the demand 17.01.2001 | Date of completion of this report 15.11.2001 |
| Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88 | Authorized officer Patrik Blidefalk/AE Telephone No. 08-782 25 00 |

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE00/01376

I. Basis of the report

1. With regard to the **elements** of the international application:*

- ☒ the international application as originally filed
- ☐ the description:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the claims:
 pages _____, as originally filed
 pages _____, as amended (together with any statement) under article 19
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the drawings:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the sequence listing part of the description:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language English which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☒ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheet/fig _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE00/01376

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

| | | | |
|-------------------------------|--------|-------------|-----|
| Novelty (N) | Claims | <u>1-13</u> | YES |
| | Claims | | NO |
| Inventive step (IS) | Claims | <u>1-13</u> | YES |
| | Claims | | NO |
| Industrial applicability (IA) | Claims | <u>1-13</u> | YES |
| | Claims | | NO |

2. Citations and explanations (Rule 70.7)

Prior art

Prior art, cited in the search report, consists of the following documents:

(D1) US 5 561 611, A

(D2) US 5 696 850, A

(D3) "Digital Image Processing", R.F. Gonzales. R.E. Woods, Addison-Wesley Publishing Company Inc. 1992, ISBN 0-201-60078-1, pages 189-201

D1 and D2 describe signal restoration methods and image-sharpening methods for noisy signal obtained from optical imaging system e.g. microscopes. However, the methods in D1 and D2 are more complicated and needs more processing then the claimed invention. Therefore, D1 and D2 merely defines state of the art.

D3 describes some basics about spatial filtering of image data. However, it does not describe the claimed invention, it merely define state of the art.

Statement of reasons

None of documents D1-D3, nor any combination of them, describe such a microscope, as claimed in claims 1-12, or such a method, as claimed in claim 13. There is also no teaching in the cited art leading a skilled person to this microscope or this method. Therefore, the claimed invention is novel and involves an inventive step.

Accordingly, claims 1-13 are novel (N) and fulfil the requirements of inventive step (IS) and industrial applicability (IA).

PCT REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty

| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| For receiving Office use only | |
| International Application No. | PCT/SE 00/01376 |
| International Filing Date | 29-06-2000 |
| <div style="border: 1px solid black; padding: 2px; text-align: center;"> The Swedish Patent Office PCT International Application </div> | |
| Name of receiving Office and "PCT International Application" | |
| Applicant's or agent's file reference (if desired) (12 characters maximum) | 2001521 |

| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Box No. I TITLE OF INVENTION | |
| MICROSCOPE FILTER FOR AUTOMATIC CONTRAST ENHANCEMENT | |
| Box No. II APPLICANT | |
| Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.) CELLAVISION AB Forskningsbyn Ideon SE-223 70 LUND Sweden | <input type="checkbox"/> This person is also inventor. Telephone No. Facsimile No. Teleprinter No. |
| State (that is, country) of nationality: Sweden | State (that is, country) of residence: Sweden |
| This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input checked="" type="checkbox"/> all designated States except the United States of America <input type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box | |
| Box No. III FURTHER APPLICANT(S) AND/OR /FURTHER INVENTOR(S) | |
| Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.) HEYDEN, Anders Skogslyckevägen 9 SE-240 10 DALBY Sweden | This person is: <input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only (If this check-box is marked, do not fill in below.) |
| State (that is, country) of nationality: Sweden | State (that is, country) of residence: Sweden |
| This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box | |
| <input type="checkbox"/> Further applicants and/or (further) inventors are indicated on a continuation sheet | |
| Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE | |
| The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: <input checked="" type="checkbox"/> agent <input type="checkbox"/> common representative | |
| Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) AWAPATENT AB Box 5117 SE-200 71 MALMÖ SWEDEN | Telephone No. +46 40 98 51 00 Facsimile No. +46 40 26 05 16 Teleprinter No. |
| <input type="checkbox"/> Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent | |

Box No. V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

Regional Patent

- ☒ **AP** **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ **EA** **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ **EP** **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT (if other kind of protection or treatment desired, specify on dotted line)

National Patent (if other kind of protection or treatment desired, specify on dotted line):

- | | | |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| <input checked="" type="checkbox"/> AE United Arab Emirates | <input checked="" type="checkbox"/> LR Liberia | |
| <input checked="" type="checkbox"/> AL Albania | <input checked="" type="checkbox"/> LS Lesotho | |
| <input checked="" type="checkbox"/> AM Armenia | <input checked="" type="checkbox"/> LT Lithuania | |
| <input checked="" type="checkbox"/> AT Austria +Utility Model | <input checked="" type="checkbox"/> LU Luxembourg | |
| <input checked="" type="checkbox"/> AU Australia | <input checked="" type="checkbox"/> LV Latvia | |
| <input checked="" type="checkbox"/> AZ Azerbaijan | <input checked="" type="checkbox"/> MA Morocco | |
| <input checked="" type="checkbox"/> BA Bosnia and Herzegovina | <input checked="" type="checkbox"/> MD Republic of Moldova | |
| <input checked="" type="checkbox"/> BB Barbados | <input checked="" type="checkbox"/> MG Madagascar | |
| <input checked="" type="checkbox"/> BG Bulgaria | <input checked="" type="checkbox"/> MK The former Yugoslav Republic of Macedonia | |
| <input checked="" type="checkbox"/> BR Brazil | | |
| <input checked="" type="checkbox"/> BY Belarus | <input checked="" type="checkbox"/> MN Mongolia | |
| <input checked="" type="checkbox"/> CA Canada | <input checked="" type="checkbox"/> MW Malawi | |
| <input checked="" type="checkbox"/> CH and LI Switzerland and Liechtenstein | <input checked="" type="checkbox"/> MX Mexico | |
| <input checked="" type="checkbox"/> CN China | <input checked="" type="checkbox"/> NO Norway | |
| <input checked="" type="checkbox"/> CR Costa Rica | <input checked="" type="checkbox"/> NZ New Zealand | |
| <input checked="" type="checkbox"/> CU Cuba | <input checked="" type="checkbox"/> PL Poland | |
| <input checked="" type="checkbox"/> CZ Czech Republic +Utility Model | <input checked="" type="checkbox"/> PT Portugal | |
| <input checked="" type="checkbox"/> DE Germany +Utility Model | <input checked="" type="checkbox"/> RO Romania | |
| <input checked="" type="checkbox"/> DK Denmark +Utility Model | <input checked="" type="checkbox"/> RU Russian Federation | |
| <input checked="" type="checkbox"/> DM Dominica | <input checked="" type="checkbox"/> SD Sudan | |
| <input checked="" type="checkbox"/> EE Estonia +Utility Model | <input checked="" type="checkbox"/> SE Sweden | |
| <input checked="" type="checkbox"/> ES Spain | <input checked="" type="checkbox"/> SG Singapore | |
| <input checked="" type="checkbox"/> FI Finland +Utility Model | <input checked="" type="checkbox"/> SI Slovenia | |
| <input checked="" type="checkbox"/> GB United Kingdom | <input checked="" type="checkbox"/> SK Slovakia +Utility Model | |
| <input checked="" type="checkbox"/> GD Grenada | <input checked="" type="checkbox"/> SL Sierra Leone | |
| <input checked="" type="checkbox"/> GE Georgia | <input checked="" type="checkbox"/> TJ Tajikistan | |
| <input checked="" type="checkbox"/> GH Ghana | <input checked="" type="checkbox"/> TM Turkmenistan | |
| <input checked="" type="checkbox"/> GM Gambia | <input checked="" type="checkbox"/> TR Turkey | |
| <input checked="" type="checkbox"/> HR Croatia | <input checked="" type="checkbox"/> TT Trinidad and Tobago | |
| <input checked="" type="checkbox"/> HU Hungary | <input checked="" type="checkbox"/> TZ United Republic of Tanzania | |
| <input checked="" type="checkbox"/> ID Indonesia | <input checked="" type="checkbox"/> UA Ukraine | |
| <input checked="" type="checkbox"/> IL Israel | <input checked="" type="checkbox"/> UG Uganda | |
| <input checked="" type="checkbox"/> IN India | <input checked="" type="checkbox"/> US United States of America | |
| <input checked="" type="checkbox"/> IS Iceland | | |
| <input checked="" type="checkbox"/> JP Japan | <input checked="" type="checkbox"/> UZ Uzbekistan | |
| <input checked="" type="checkbox"/> KE Kenya | <input checked="" type="checkbox"/> VN Viet Nam | |
| <input checked="" type="checkbox"/> KG Kyrgyzstan | <input checked="" type="checkbox"/> YU Yugoslavia | |
| <input checked="" type="checkbox"/> KP Democratic People's Republic of Korea | <input checked="" type="checkbox"/> ZA South Africa | |
| | <input checked="" type="checkbox"/> ZW Zimbabwe | |
| <input checked="" type="checkbox"/> KR Republic of Korea +Utility Model | Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet: | |
| <input checked="" type="checkbox"/> KZ Kazakhstan | | |
| <input checked="" type="checkbox"/> LC Saint Lucia | <input checked="" type="checkbox"/> DZ Algeria | <input checked="" type="checkbox"/> MZ Mozambique |
| <input checked="" type="checkbox"/> LK Sri Lanka | <input checked="" type="checkbox"/> AG Antigua and Barbuda | <input checked="" type="checkbox"/> BZ Belize |

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)

Sheet No. 3

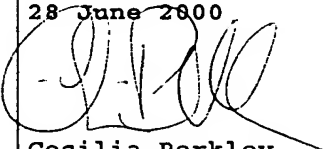
| Box No. VI PRIORITY CLAIM | | <input type="checkbox"/> Further priority claims are indicated in the Supplement Box. | | |
|-----------------------------------------------------------|----------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------|------------------------------------------------|
| Filing date of earlier application (day/month/year) | Number of earlier application | Where earlier application is: | | |
| | | national application: country | regional application:* regional Office | international application: receiving Office |
| item (1) 9 July 1999 (09.07.99) | 9902641-1 | SWEDEN | | |
| item (2) 24 August 1999 (24.08.99) | 60/150 440 | USA | | |
| item (3) | | | | |

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office) identified above as item(s): 1

* Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.

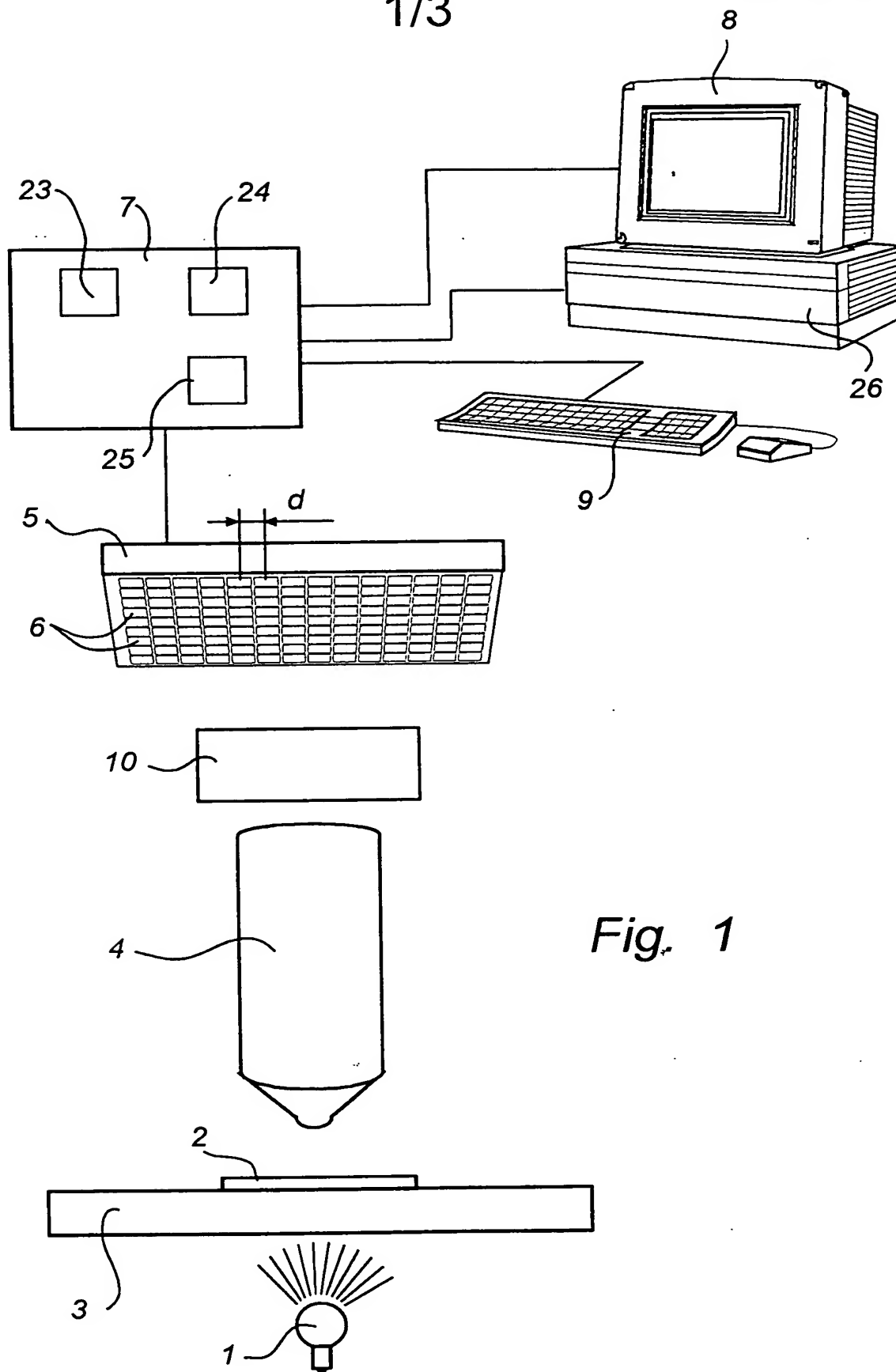
| Box No. VII INTERNATIONAL SEARCHING AUTHORITY | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Choice of International Searching Authority (ISA) (If two or more International Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used): | Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority): Date (day/month/year) <u>SE 1999</u> Number <u>01033</u> Country (or regional Office) <u>Sweden</u> <u>9 July 1999</u> <u>9902641-1</u> |

| Box No. VIII CHECK LIST; LANGUAGE OF FILING | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| This international application contains the following number of sheets: request : 3 ✓ description (excluding sequence listing part) : 9 ✓ claims : 3 ✓ abstract : 1 ✓ drawings : 3 ✓ sequence listing part of description : Total number of sheets : 19 ✓ | This international application is accompanied by the item(s) marked below: 1. <input checked="" type="checkbox"/> fee calculation sheet 2. <input checked="" type="checkbox"/> separate signed power of attorney 3. <input type="checkbox"/> copy of general power of attorney; reference No., if any: 4. <input type="checkbox"/> statement explaining lack of signature 5. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s): 6. <input checked="" type="checkbox"/> translation of international applications into (language): <u>English</u> ✓ 7. <input type="checkbox"/> separate indications concerning deposited microorganism or other biological material 8. <input type="checkbox"/> nucleotide and/or amino acid sequence listing in computer readable form 9. <input checked="" type="checkbox"/> other (specify): <u>Subauthorisation, Copy of ITS-report</u> |
| Figure of the drawings which should accompany the abstract: <u>1</u> | Language of filing of the international application: <u>Swedish</u> |

| Box No. IX SIGNATURE OF APPLICANT OR AGENT | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request). <u>28 June 2000</u>  Cecilia Perklev Authorised Agent | |

| For receiving Office use only | | 2. Drawings: <input checked="" type="checkbox"/> received: <input type="checkbox"/> not received: |
|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| 1. Date of actual receipt of the Purported international application: | <u>29-06-2000</u> | |
| 3. Corrected date of actual receipt due to later but Timely received papers or drawings completing the purported international application: | | |
| 4. Date of timely receipt of the required Corrections under PCT Article 11(2): | | |
| 5. International Searching Authority (if two or more are competent): ISA/ <u>SE</u> | 6. <input type="checkbox"/> Transmittal of search copy delayed until search fee is paid. | |

| For International Bureau use only | |
|----------------------------------------------------------------------------------------------|-------------------------------------------|
| Date of receipt of the record copy by the International Bureau: | <u>09 AUGUST 2000</u> (<u>09.08.00</u>) |
| Form PCT/RO/101 (last sheet) (July 1998; reprint January 2000) See Notes to the request form | |



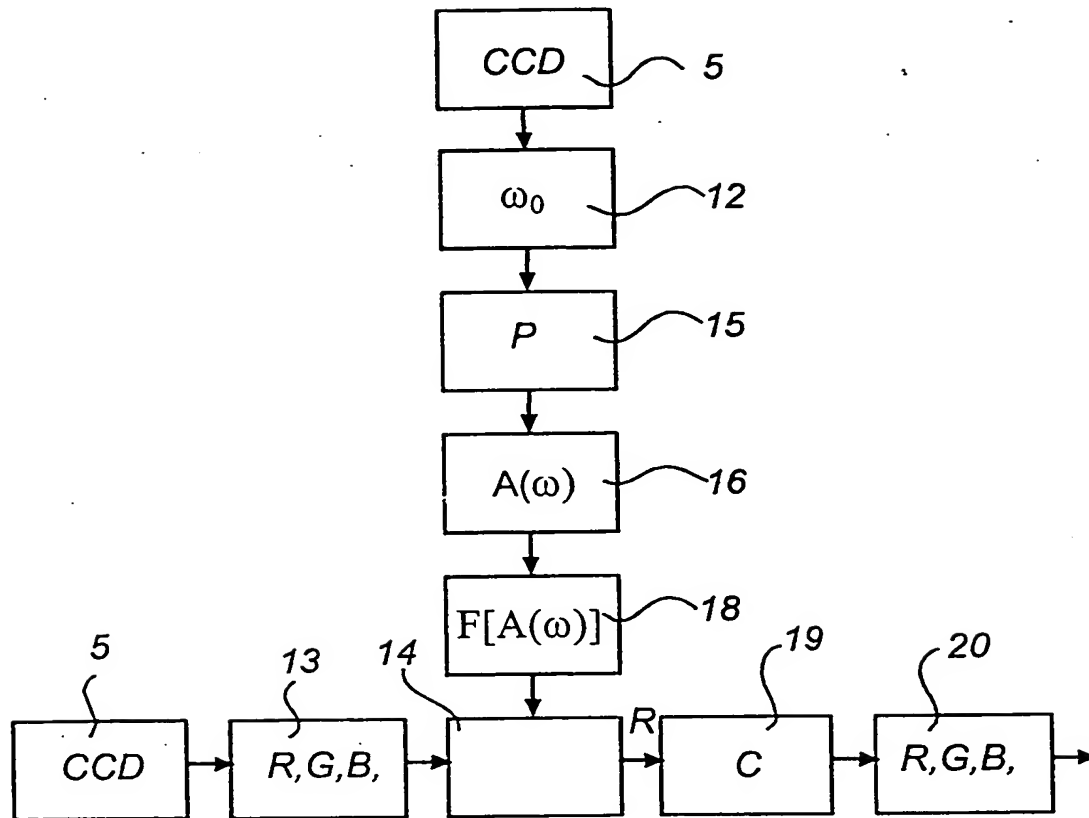


Fig. 2

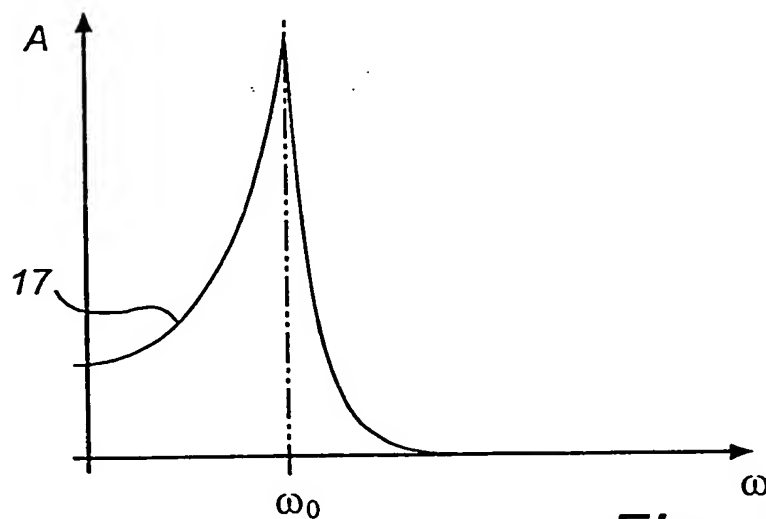
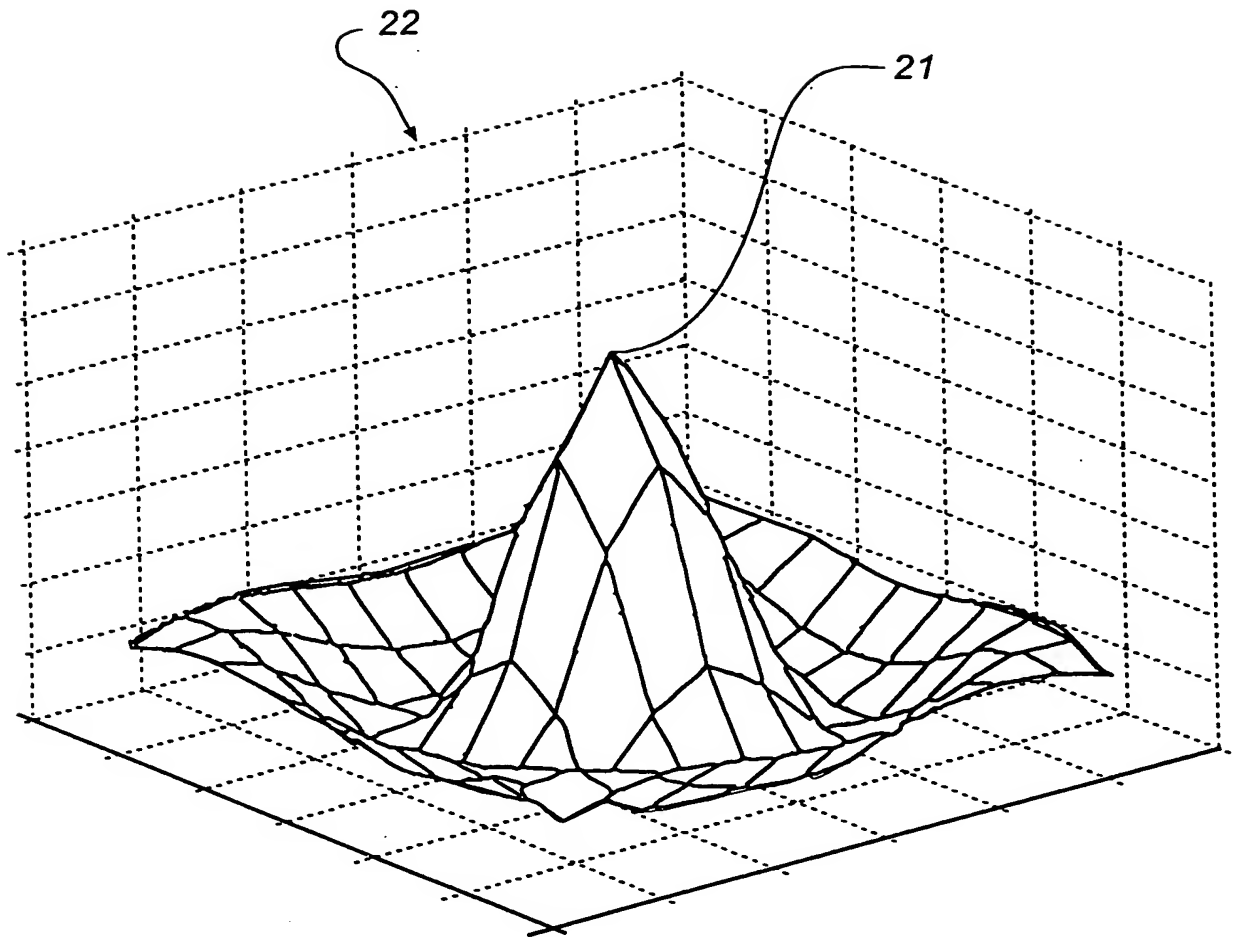


Fig. 3

*Fig. 4*

MIKROSKOP-FILTER FÖR AUTOMATISK KONTRASTSKÄRPNING

Tekniskt område

Föreliggande ansökan avser ett mikroskop med ett bildbehandlingssystem och ett förfarande för ett sådant.

Teknikens ståndpunkt

5 Mikroskop är ofta försedda med en kamera för registrering av digitala bilder. Den digitala bilden kan sedan behandlas på ett antal olika sätt. Exempelvis studeras biologiska preparat med mikroskop försedda med bildbehandlingssystem. Bildbehandlingssystemet kan då
10 användas för igenkänning av en viss sorts organismer eller celler för att automatiskt kunna bestämma förekomsten av organismen eller cellen i provet.

Emellertid är det ibland svårt att erhålla en tillräckligt skarp bild för att enkelt kunna utföra en automatisk igenkänning och bestämning av ett speciellt slags
15 organismer. Detta gäller speciellt för små organismer eller celler.

För att enklare kunna utföra automatisk igenkänning är det möjligt att använda digitala filter för att förbättra kontrasten i bilden och därigenom göra det lättare
20 för bildbehandlingssystemet att automatiskt känna igen cellerna eller organismerna.

En standardmetod för att förbättra kontrasten i en bild är den så kallade High-Boostmetoden, varvid bilden
25 multipliceras med en faktor varefter en lågpåssfiltrerad bild subtraheras från resultatet av multiplikationen.

I det amerikanska patentet 5,696,850 beskrivs ett förfarande och ett system som använder en algoritm för att öka skärpan i reproducerade bilder, varvid systemet
30 har en digital kamera och en reproduktionsanordning. Enligt förfarandet bestäms kamerans och reproduktionsanordningens överföringsfunktioner genom att man mäter dem noggrant. Mätningen kräver dock avancerad och dyr apparatur och görs i en ledd åt gången eftersom det är

besvärligt att göra en tvådimensionell mätning av överföringsfunktionen. Dessutom måste mätningen av den optiska överföringsfunktionen göras varje gång något har förändrats i det optiska systemet. Därefter används den
5 inversa Fourier-transformen av de båda kombinerade överföringsfunktionerna för att beräkna ett en-dimensionellt filter. Filtret används för att filtrera en registrerad bild genom att först applicera filtret i en ledd och därefter i en ledd som är vinkelrät mot den första.

10 Emellertid erhålls inte tillräckligt bra resultat med de kända teknikerna. Det är inte heller möjligt att mäta överföringsfunktionen för ett mikroskop lika noga som för en kamera.

Ett annat problem med förfarandet och anordningen
15 enligt det amerikanska patentet är att bruset vid höga frekvenser kommer att förstärkas okontrollerat om överföringsfunktionens värde är litet för höga frekvenser. Dessutom erhåller man inte ett fullgott resultat med två en-dimensionella filter applicerade efter varandra.

20 Sålunda finns det ett behov av ett förfarande och ett mikroskop med ett bildbehandlingssystem som ökar skärpan i en bild samtidigt som bruset begränsas.

Sammanfattning av uppfinningen

Ett ändamål med föreliggande ansökan är att åstadkomma ett mikroskop, vilket ökar skärpan samtidigt som
25 bruset begränsas i en bild tagen med mikroskopet.

Ett ytterligare ändamål med föreliggande ansökan är att tillhandahålla ett förfarande för upptagning och
30 behandling av digitala bilder för att erhålla skarpa bilder.

Dessa ändamål uppfylls med ett mikroskop och ett förfarande för ett sådant enligt de vidhängande patentkraven.

Ett mikroskop med bildbehandlingssystem enligt
35 uppfinningen innefattar en objekthållare, optik som i ett bildplan skapar en bild av ett objekt placerat i objekthållaren, och en digital bildsensor, vilken har ett antal

sensorelement, för registrering av bilden. Ett mikroskop enligt uppfinningen utmärkes av att bildsensorn och bildplanet är anordnade så att sensorelementens spatialfrekvens är högre än den maximala spatialfrekvensen i bilden. Mikroskopet innefattar vidare åtminstone ett beräkningsorgan kopplat till bildsensorn, varvid ett första beräkningsorgan är anordnat att tillhandahålla en två-dimensionell filterfunktion, vilken väsentligen har ett första värde vid spatialfrekvensen noll, ett värde större än noll vid en spatialfrekvens över bildens maximala spatialfrekvens och ett toppvärde mellan spatialfrekvensen noll och spatialfrekvensen för det andra värdet, att beräkna ett digitalt filter som motsvarar en två-dimensionell invers transform av filterfunktionen, och att filtrera en registrerad bild med det digitala filtret.

Filterfunktionen avtar mot noll för spatialfrekvenser över toppvärdets spatialfrekvens.

Det första värdet är företrädesvis ett eftersom ingen dämpning vanligtvis förekommer vid spatialfrekvensen noll. Det är emellertid möjligt att ha en förstärkning även vid spatialfrekvensen noll i bilden.

Sensorelementens spatialfrekvens definieras som inversen av det dubbla avståndet mellan två närliggande sensorelement.

Företrädesvis är mikroskopet anordnat att beräkna ett digitalt filter då en användare initierar en sådan beräkning. Alternativt är mikroskopet anordnat att beräkna ett digitalt filter varje gång en ny bild registreras med bildsensorn, vilket emellertid inte ger några större fördelar.

Genom att man använder ett tvådimensionellt filter är det möjligt att erhålla ett rotationssymmetriskt resultat. Genom att sensorelementens spatialfrekvens är högre än den maximala spatialfrekvensen i bilden är det möjligt att använda ett digitalt filter vilket motsvarar en filterfunktion som har ett värde skilt från noll vid

frekvenser över bildens maximala spatialfrekvens. Användning av ett sådant digitalt filter leder till brusreduktion i bilden.

5 Filterfunktionen utgörs enligt en alternativ utföringsform av en faltningsform av två endimensionella filterfunktioner. Det digitala filtret blir då emellertid inte rotationssymmetriskt.

10 Bildsensorn är med fördel en halvledarsensor i form av exempelvis en CMOS-sensor eller en CCD (charge coupled device) som är uppbyggd av ett antal sensorelement fördelade på lika inbördes avstånd. Sensorelementets spatialfrekvens är inversen av avståndet mellan två närliggande sensorelement.

15 Bildsensorn kan emellertid vara någon annan sorts bildsensor som exempelvis en vidicon. Det väsentliga för uppfinningen är att bildsensorn har en bättre upplösning än bildens högsta spatialfrekvens.

20 Företrädesvis har sensorelementen en spatialfrekvens som är åtminstone 1,5 gånger, med fördel åtminstone 2 gånger högre, än den högsta spatialfrekvensen i bilden.

Enligt en föredragen utföringsform av föreliggande uppfinning innefattar mikroskopet även ett inmatningsorgan för inmatning av värden som ger information om filterfunktionen.

25 Företrädesvis är mikroskopet anordnat att göra en uppskattning av gränsfrekvensen för optiken genom registrering av en bild med bildsensorn. Den registrerade bilden Fouriertransformeras så att en bild i frekvensplanet erhålls. Det första beräkningsorganet beräknar
30 utgående från den Fouriertransformerade bilden en gränsfrekvens. Den integrerade signalen upp till gränsfrekvensen utgör huvuddelen av den totala ljusenergin i bilden och med fördel åtminstone 90%, företrädesvis minst 95%, av den totala ljusenergin i den transformerade bilden.
35 Den på det beskrivna sättet uppmätta gränsfrekvensen är inte densamma som den högsta frekvens det optiska syste-

met släpper igenom, men är en användbar uppskattning av den.

Gränsfrekvensen används vid beräkningen av läget för filterfunktionens toppvärde. Det är fördelaktigt att låta
5 toppvärdets läge bero även på de via inmatningsorganet inmatade värdena för filterfunktionens utseende.

Om mikroskopet är anordnat att uppskatta gränsfrekvensen görs uppskattningen företrädesvis då en användare initierar en sådan uppskattning, men alternativt görs uppskattningen varje gång en ny bild registreras.
10

Filterfunktionen är med fördel strängt växande fram till gränsfrekvensen och därefter strängt avtagande så att filterfunktionen fram till gränsfrekvensen så långt
15 som möjligt överensstämmer med inversen av en verklig överföringsfunktion. En verklig överföringsfunktion är i allmänhet strängt avtagande fram till den högsta frekvens det optiska systemet släpper igenom.

Det är möjligt att inom ramen för uppfinningen ha en
20 filterfunktion som varken är strängt växande fram till gränsfrekvensen eller strängt avtagande efter gränsfrekvensen.

Det är fördelaktigt att låta filterfunktionen vara kontinuerligt deriverbar eftersom detta möjliggör ett
25 digitalt filter med mindre spatiell utsträckning och därmed en snabbare filtrering.

Ovanstående särdrag kan givetvis kombineras i samma utföringsform.

För att ytterligare belysa uppfinningen kommer i det
30 följande detaljerade utföringsformer av uppfinningen att beskrivas, utan att emellertid uppfinningen skall anses begränsad härtill.

Kort ritningsbeskrivning

Figur 1 visar en schematisk bild av ett mikroskop i
35 enlighet med en utföringsform av föreliggande uppfinning.

Figur 2 visar ett blockschema över funktionen hos ett mikroskop enligt uppfinningen.

Figur 3 visar filterfunktionen som funktion av frekvensen i ett mikroskop enligt föreliggande uppfinning.

Figur 4 visar ett digitalt filter enligt föreliggande uppfinning.

Detaljerad beskrivning av uppfinningen

Fig 1 visar en schematisk bild av ett mikroskop i enlighet med föreliggande uppfinning. Mikroskopet har en ljuskälla 1, som belyser ett objekt 2, placerat på en objekthållare 3. Ljus från objektet samlas in med ett mikroskopobjektiv 4. En digital bildsensor 5 är anordnad på ett avstånd från mikroskopobjektivet 4. Den digitala bildsensorn är enligt denna föredragna utföringsform en CCD. CCD:n 5, mikroskopobjektivet 4 och objektet 2 är anordnade på inbördes avstånd så att mikroskopobjektivets bildplan sammanfaller med bildsensorns 5 yta. CCD:n är uppbyggd med ett stort antal sensorelement 6, vilka har ett inbördes avstånd d. Varje bildelement motsvarar en punkt i en digital bild. Bildsensorn 5 är kopplad till ett bildbehandlingsorgan 7; vilket i sin tur är kopplat till en display 8 och ett inmatningsorgan i form av ett tangentbord 9. I bildbehandlingsorganet finns anordnat ett första beräkningsorgan 24 och ett andra beräkningsorgan 25. Mellan mikroskopobjektivet 4 och CCD:n 5 finns linser 10 som används för att överföra bilden till CCD:n 5. Det optiska systemet bestående av mikroskopobjektivet 4 och optiken 10 har en sammanlagd överföringsfunktion som beskriver hur olika spatialfrekvenser i objektet 2 överförs till bildplanet. Beroende på utformningen hos objektivet 4 och linserna 10 överförs olika höga spatialfrekvenser från objektet 2. Den maximala spatialfrekvens som överförs från objektet 2 till CCD:n 5 definieras vanligen som det optiska systemets upplösning. Således kommer endast strukturer som motsvarar en viss minsta storlek hos objektet att kunna urskiljas i bilden. Emellertid kan bildens storlek varieras genom att variera den inbördes placeringen av CCD:n 5, mikroskopobjektivet 4

och objektet 2. Sensorelementens spatialfrekvens definieras som inversen av deras dubbla inbördes avstånd $2d$. Enligt uppfinningen anordnas objektet 2, mikroskopobjektivet 4, linserna 10 och CCD:n 5 så att sensorelementens spatialfrekvens är större än bildens maximala spatialfrekvens. Sensorelementens spatialfrekvens är företrädesvis 1,5 gånger större än bildens maximala spatialfrekvens och med fördel åtminstone två gånger större än bildens maximala spatialfrekvens för att
5
10 erhålla brusreducering.

Då ett objekt 2 placeras på objekthållaren 3 kommer en bild att registreras av bildsensorn 5. Den registrerade bilden kopplas vidare till bildbehandlingsorganet 7, vilket behandlar bilden innan den visas på displayen 8.
15 Bildbehandlingen i bildbehandlingsorganet 7 påverkas av parametrar som matas in via tangentbordet 9.

I fig 2 visas ett blockschema över funktionen hos bildbehandlingsorganet 7. Den registrerade bilden från CCD:n 5 matas in överst i figuren till block 12 och
20 nederst i figuren till block 13. I block 13 görs en uppdelning i bildens färgkomponenter varefter den uppdelade bilden skickas vidare till block 14 för filtrering med ett digitalt filter. I block 12 bestäms en gränsfrekvens (ω_0) genom att den registrerade bilden transformeras, varefter ω_0 beräknas som den frekvens under vilken 95% av den integrerade signalen i den transformerade bilden finns. Beräkningen av ω_0 kan göras varje gång en ny bild tages eller då en användare av mikroskopet initierar en bestämning av ω_0 .
25

Enligt den föredragna utföringsformen beräknas ett digitalt filter då en användare initierar en sådan beräkning via tangentbordet 9.
30

I fig 3 visas en filterfunktion som funktion av frekvensen vilken beskriver en förstärkning som funktion av frekvensen.
35

I block 15 hämtas parametrar för filtrets överföringsfunktion in från tangentbordet eller från ett

minne 23 i bildbehandlingsorganet. Exempel på de parametrar som kan hämtas in från tangentbordet 9 vid block 15 är filtrets förstärkning vid gränsfrekvensen, gränsfrekvensens läge och filterfunktionens utseende över respektive under gränsfrekvensen. I block 16 bestäms filtrets överföringsfunktion 17 utgående från parametrarna som hämtas in i block 15. Filterfunktionen 17 bestäms enligt:

$$H_f(\omega) = \begin{cases} e^{(\omega/\omega_0)^2 \alpha}, & \omega \leq \omega_0, \\ e^{\alpha \left(\frac{\omega_1^2 + \omega_0^2}{\omega_1^2 + \omega^2} \right) \gamma}, & \omega \geq \omega_0, \end{cases}$$

där α , γ och ω_1 är parametrar som användaren kan modifiera vid inmatningsorganet 9. Parametern ω_0 kan antingen definieras av användaren eller bestämmas automatiskt av systemet och betecknar gränsfrekvensen. Förstärkningen vid gränsfrekvensen bestäms av α . γ och ω_1 bestämmer hur snabbt filtret klingar av vid höga frekvenser.

Således är filterfunktionen tvådimensionell och beroende på beloppet av frekvensen ω men oberoende av någon vinkelparameter, varvid en cirkulärsymmetrisk funktion erhålls.

Filterfunktionen kan dock ha något annat utseende och kan exempelvis beskrivas av ett polynom upp till gränsvärdet och ett annat polynom över gränsvärdet. Filterfunktionen 17 har väsentligen värdet 1 för frekvensen noll och ett toppvärde vid gränsfrekvensen (ω_0). Efter gränsfrekvensen ω_0 är funktionen avtagande. Filterfunktionen har dock ett värde skilt från noll över en frekvens som överstiger den maximala spatialfrekvensen i bilden. Gränsfrekvensen överensstämmer huvudsakligen med den maximala spatialfrekvensen i bilden. Åter med hänvisning till fig 2 görs i block 18 en två-dimensionell invers transform av filterfunktionen som beräknades i block 16. Den inverstransformerade filterfunktionen digitaliseras och skärs av till en lämplig storlek för att utgöra

ett digitalt filter för den registrerade bilden. I block 14 filtreras den färguppdelade bilden tvådimensionellt med det digitala filtret. Därefter görs en frivillig grånivåtransformation i block 19 varefter färgerna i bilden åter sätts samman i block 20. Grånivåtransformationen görs om det finns risk för att grånivåerna har hamnat utanför tillåtna värden vid filtreringen. Efter bildbehandlingen visas bilden på displayen 8 eller lagras i ett lagringsorgan 26.

10 I fig 4 visas ett exempel på ett digitalt filter 22 som används i block 14. Såsom framgår av fig 4 är filtret cirkulärsymmetriskt runt toppen 21. Då bilden filtreras i block 14 multipliceras värdet i en bildpunkt med ett värde som motsvarar filtret i punkten 21 och adderas till
15 resultatet från multiplikationerna mellan de närliggande bildpunkterna och motsvarande värde i filtret.

En fackman inom området inser att uppfinningen ej är begränsad till den här visade utföringsformen utan att många modifieringar är möjliga inom ramen för uppfinningen. Exempelvis kan block 12 i fig 2 uteslutas och filterfunktionen bestämmas helt med parametrar som matas in via tangentbordet 9 i fig 1. En fackman inser också att block 20
20 13 och 20 kan uteslutas om bilden inte är en färgbild.

PATENTKRAV

1. Mikroskop innefattande
en objekthållare (3),
5 optik som i ett bildplan skapar en bild av ett
objekt (2) som är placerat i objekthållaren,
en digital bildsensor (5), vilken har ett antal
sensorelement (6), för registrering av bilden, k ä n -
n e t e c k n a t av att bildsensorn och bildplanet är
10 så anordnade att sensorelementens (6) spatialfrekvens är
högre än den maximala spatialfrekvensen i bilden, varvid
mikroskopet vidare innefattar åtminstone ett första
beräkningsorgan (24) vilket är kopplat till bildsensorn
(5) och vilket är anordnat
15 att tillhandahålla en två-dimensionell filterfunk-
tion, vilken väsentligen har ett första värde vid
spatialfrekvensen noll, ett andra värde vilket är skilt
från noll vid en spatialfrekvens över bildens maximala
spatialfrekvens och ett toppvärde mellan spatialfrek-
20 vensen noll och spatialfrekvensen för det andra värdet,
att beräkna ett digitalt filter som motsvarar en
två-dimensionell invers Fouriertransform av filterfunk-
tionen, och
att filtrera en registrerad bild med det digitala
25 filtret.
2. Mikroskop enligt patentkrav 1, k ä n n e -
t e c k n a t av att det även innefattar ett inmat-
ningsorgan (9) kopplat till beräkningsorganet för
inmatning av värden som ger information om åtminstone
30 något av filterfunktionens toppvärde, toppvärdets
spatialfrekvens, filterfunktionen för spatialfrekvenser
under toppvärdets spatialfrekvens, eller filterfunktionen
för spatialfrekvenser över toppvärdets spatialfrekvens,
varvid inmatningsorganet är kopplat till beräknings-
35 organet och de inmatade värdena används av beräknings-
organet för tillhandahållande av filterfunktionen.

3. Mikroskop enligt patentkrav 1 eller 2, k ä n -
n e t e c k n a t av att det även innefattar ett andra
beräkningsorgan (25), vilket är kopplat till bildsensorn
och det första beräkningsorganet, och vilket är anordnat
5 att Fouriertransformera den registrerade bilden,
att bestämma en gränsfrekvens under vilken huvud-
delen av ljusenergin i den transformerade bilden finns,
och

att förse det första beräkningsorganet med gräns-
10 frekvensen som ett värde på toppvärdets läge.

4. Mikroskop enligt patentkrav 3, k ä n n e -
t e c k n a t av att gränsfrekvensen bestäms som den
frekvens under vilken åtminstone 90% av energin i bilden
finns.

15 5. Mikroskop enligt patentkrav 1, 2 eller 3,
k ä n n e t e c k n a t av att sensorelementens spatial-
frekvens är åtminstone 1,5 gånger högre, och företrädes-
vis åtminstone 2 gånger högre, än den maximala spatial-
frekvensen i bilden.

20 6. Mikroskop enligt patentkrav 3 eller 4, k ä n -
n e t e c k n a t av att sensorelementens spatial-
frekvens är åtminstone 1,5 gånger högre, och företrädes-
vis åtminstone 2 gånger högre, än gränsfrekvensen.

7. Mikroskop enligt något av föregående patentkrav,
25 k ä n n e t e c k n a t av att filterfunktionen (17) är
kontinuerlig och strängt växande från nollfrekvens till
toppvärdets läge och strängt avtagande mot noll för
ökande frekvenser från toppvärdets läge.

8. Mikroskop enligt något av föregående patentkrav,
30 k ä n n e t e c k n a t av att filterfunktionen utgörs
av en faltning av två en-dimensionella filterfunktioner.

9. Mikroskop enligt något av föregående patentkrav,
k ä n n e t e c k n a t av att den filtrerade bilden
lagras i ett lagringsorgan (26).

35 10. Mikroskop enligt något av föregående patentkrav,
k ä n n e t e c k n a t av att det även innefattar en
display (8) på vilken den filtrerade bilden visas.

11. Mikroskop enligt något av föregående patentkrav,
k ä n n e t e c k n a t av att det första beräknings-
organet är anordnat

5 att dela upp den registrerade bilden i färgkomponen-
ter, och

att tillhandhålla ett digitalt filter för var och en
av färgkomponenterna.

12. Mikroskop enligt något av föregående patentkrav,
k ä n n e t e c k n a t av att det första värdet väsent-
10 ligen är ett.

13. Förfarande för ett mikroskop, k ä n n e -
t e c k n a t av stegen

15 att anordna en bildsensor (5) som har ett flertal
sensorelement (6), optik (4, 10) och ett objekt (2) på
inbördes avstånd så att en bild av objektet skapas på
bildsensorn (5), varvid sensorelementens (6) spatial-
frekvens är högre än den maximala spatialfrekvensen i
bilden,

20 att registrera bilden med bildsensorn (5),
att tillhandahålla en två-dimensionell filter-
funktion, vilken väsentligen har ett första värde vid
spatialfrekvensen noll, ett andra värde skilt från noll
vid en spatialfrekvens som är högre än bildens maximala
spatialfrekvens och ett toppvärde mellan spatialfrek-
25 vensen noll och spatialfrekvensen för det andra värdet,

att beräkna ett digitalt filter som motsvarar en
två-dimensionell invers Fouriertransform av filterfunk-
tionen, och

30 att filtrera den registrerade bilden med det digi-
tala filtret.

SAMMANDRAG

Ett mikroskop innefattar en objekthållare (3),
optik som i ett bildplan skapar en bild av ett objekt (2)
5 som är placerat i objekthållaren, en digital bildsensor
(5), vilken har ett antal sensorelement (6), för
registrering av bilden. Bildsensorn och bildplanet är
anordnade så att sensorelementens (6) spatialfrekvens är
högre än den maximala spatialfrekvensen i bilden. Mikro-
10 skopet innefattar vidare åtminstone ett första beräk-
ningsorgan (24) vilket är kopplat till bildsensorn (5)
och vilket är anordnat att tillhandahålla en två-dimen-
sionell filterfunktion, vilken väsentligen har värdet ett
vid spatialfrekvensen noll, ett värde större än noll vid
15 en spatialfrekvens över bildens maximala spatialfrekvens
och ett toppvärde mellan nämnda frekvenser, att beräkna
ett digitalt filter som motsvarar en två-dimensionell
invers Fouriertransform av filterfunktionen, och att
filtrera en registrerad bild med det digitala filtret.

20

25

30 Publ.bild = Fig 1

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
18 January 2001 (18.01.2001)

PCT

(10) International Publication Number
WO 01/04683 A1

(51) International Patent Classification: G02B 21/00.
21/36, G06T 5/00

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(21) International Application Number: PCT/SE00/01376

(22) International Filing Date: 29 June 2000 (29.06.2000)

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(25) Filing Language: Swedish

(26) Publication Language: English

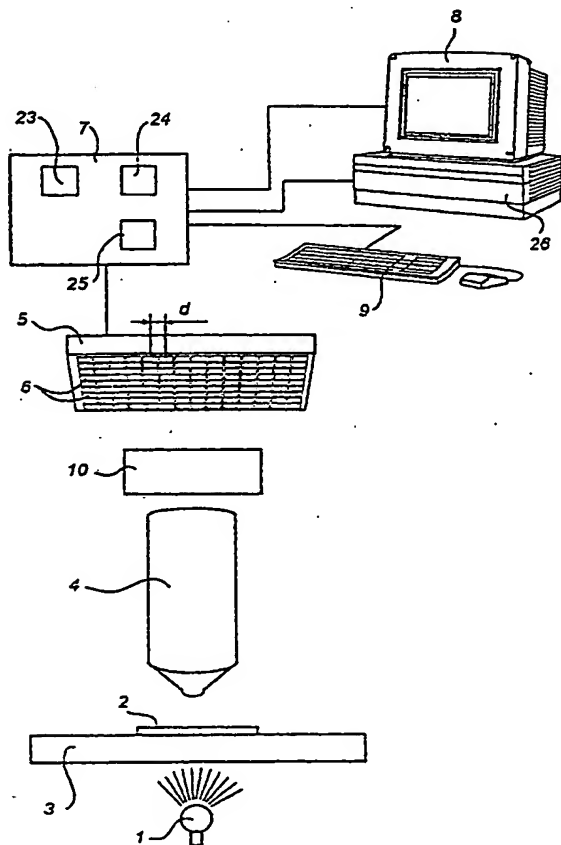
(30) Priority Data:
9902641-1 9 July 1999 (09.07.1999) SE
60/150,440 24 August 1999 (24.08.1999) US

(81) Designated States (national): AE, AG, AL, AM, AT, AT
(utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA,
CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility
model), DK, DK (utility model), DM, DZ, EE, EE (utility
model), ES, FI, FI (utility model), GB, GD, GE, GH, GM,
HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KR (utility
model), KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG,
MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD,
SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT,
TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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[Continued on next page]

(54) Title: MICROSCOPE FILTER FOR AUTOMATIC CONTRAST ENHANCEMENT



(57) Abstract: A microscope comprises an object holder (3), optics which in an image plane form an image of an object (2) which is placed in the object holder, a digital image sensor (5) which has a number of sensor elements (6) for recording the image. The image sensor and the image plane are arranged in such manner that the spatial frequency of the sensor elements (6) is higher than the maximum spatial frequency of the image. The microscope further comprises at least a first calculating means (24) which is connected to the image sensor (5) and which is adapted to provide a two-dimensional filter function, which essentially has the value one at the spatial frequency zero, a value higher than zero at a spatial frequency above the maximum spatial frequency of the image and a peak value between said frequencies, to calculate a digital filter corresponding to a two-dimensional inverse Fourier transform of the filter function, and to filter a recorded image by means of the digital filter.



(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— With international search report.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MICROSCOPE FILTER FOR AUTOMATIC CONTRAST ENHANCEMENTField of the Invention

The present invention relates to a microscope having an image processing system and a method for such a microscope.

Background of the Invention

Microscopes are frequently provided with a camera for recording digital images. The digital image can then be processed in a number of different ways. For example, biological preparations are studied under a microscope provided with an image processing system. The image processing system can then be used to recognise a certain type of organisms or cells to be able to automatically determine the presence of the organism or cell in the specimen.

However, it is sometimes difficult to obtain a sufficiently sharp image to be able to easily carry out automatic recognition and determination of a special type of organisms. This relates especially to small organisms or cells.

For easier automatic recognition, it is possible to use digital filters to improve the contrast in the image and, thus, make it easier for the image processing system to automatically recognise the cells or organisms.

A standard method of improving the contrast in an image is what is referred to as the High-Boost method, in which the image is multiplied by a factor, whereupon a low-pass filtered image is subtracted from the result of the multiplication.

US Patent 5,696,850 discloses a method and a system using an algorithm for increasing the sharpness of reproduced images, the system having a digital camera and a reproduction device. According to the method, the transfer functions of the camera and the reproduction device are determined by measuring them accurately. However, the

measuring operation requires advanced and expensive apparatus and is carried out in one direction at a time since it is difficult to make a two-dimensional measurement of the transfer function. Besides, the measurement of the optical transfer function must be effected each time something has been changed in the optical system. Then the inverse Fourier transform of the two combined transfer functions is used to calculate a one-dimensional filter. The filter is used to filter a recorded image by first applying the filter in one direction and subsequently in a direction at right angles to the first.

However, satisfactory results are not achieved by the prior art techniques. Nor is it possible to measure the transfer function for a microscope in the same accurate way as for a camera.

A further problem of the method and the device according to the US patent is that the noise at high frequencies will be amplified in an uncontrolled manner if the value of the transfer function is small for high frequencies. Moreover, a satisfactory result is not achieved with two one-dimensional filters applied successively.

There is thus a need for a method and a microscope with an image processing system which increase the sharpness of an image while at the same time the noise is restricted.

Summary of the Invention

An object of the present invention is to provide a microscope, which increases the sharpness while at the same time the noise is restricted in an image taken by means of the microscope.

A further object of the present invention is to provide a method for recording and processing of digital images so as to obtain sharp images.

These objects are achieved by a microscope and a method for the same according to the appended claims.

A microscope with an image processing system according to the invention comprises an object holder, optics

which in an image plane form an image of an object placed in the image holder, and a digital image sensor, which has a number of sensor elements, for recording the image. A microscope according to the invention is characterised in that the image sensor and the image plane are arranged in such manner that the spatial frequency of the sensor elements is higher than the maximum spatial frequency of the image. The microscope further comprises at least one calculating means connected to the sensor, a first calculating means being adapted to provide a two-dimensional filter function, which essentially has a first value at the spatial frequency zero, a value greater than zero at a spatial frequency above the maximum spatial frequency of the image and a peak value between the spatial frequency zero and the spatial frequency of the second value, to calculate a digital filter corresponding to a two-dimensional inverse transform of the filter function, and to filter a recorded image by means of the digital filter.

The filter function decreases toward zero for spatial frequencies above the spatial frequency of the peak value.

The first value is preferably one since no attenuation usually occurs at the spatial frequency zero. It is, however, possible to have amplification also at the spatial frequency zero in the image.

The spatial frequency of the sensor elements is defined as the inverse of the double distance between two adjoining sensor elements.

Preferably, the microscope is adapted to calculate a digital filter when a user initiates such calculation. Alternatively, the microscope is adapted to calculate a digital filter each time a new image is recorded by means of the image sensor, which, however, does not yield any particular advantages.

By using a two-dimensional filter, it is possible to obtain a rotationally symmetrical result. By the spatial

frequency of the sensor elements being higher than the maximum spatial frequency of the image, it is possible to use a digital filter, which corresponds to a filter function which has a value different from zero at frequencies above the maximum spatial frequency of the image. The use of such a filter results in noise reduction in the image.

According to an alternative embodiment, the filter function is a convolution of two one-dimensional filter functions. The digital filter, however, will then not be rotationally symmetrical.

The image sensor is advantageously a semiconductor sensor in the form of, for instance, a CMOS sensor or a CCD (charge coupled device) which is composed of a number of sensor elements equidistantly spaced from each other. The spatial frequency of the sensor elements is the inverse of the double distance between two adjoining sensor elements.

However, the image sensor can be some other kind of image sensor such as a vidicon. What is essential for the invention is that the image sensor has a better resolution than the maximum spatial frequency of the image.

Preferably, the sensor elements have a spatial frequency which is at least 1.5 times, advantageously at least 2 times higher, than the maximum spatial frequency of the image.

According to a preferred embodiment of the present invention, the microscope also comprises an input means for inputting values providing information about the filter function.

Preferably, the microscope is adapted to make an estimate of the limit frequency of the optics by recording an image by means of the image sensor. The recorded image is Fourier-transformed so that an image in the frequency plane is obtained. The first calculating means calculates on the basis of the Fourier-transformed image a limit frequency. The integrated signal up to the limit frequency is the major part of the total light energy of the

image and advantageously at least 90%, preferably at least 95%, of the total light energy in the transformed image. The limit frequency measured in the manner described is not the same as the maximum frequency which the optical system lets through, but is a usable estimate thereof.

The limit frequency is used to calculate the position of the peak value of the filter function. It is advantageous to let the position of the peak value depend also on the values of the appearance of the filter function, which are inputted with the aid of the input means.

If the microscope is adapted to estimate the limit frequency, the estimate is preferably made when a user initiates such an estimate, but alternatively the estimate is made each time a new image is recorded.

The filter function is advantageously strictly increasing up to the limit frequency and subsequently strictly decreasing so that the filter function up to the limit frequency conforms as far as possible with the inverse of an actual transfer function. As a rule, an actual transfer function is strictly decreasing up to the maximum frequency which the optical system lets through.

It is possible within the scope of the invention to have a filter function which is neither strictly increasing up to the limit frequency nor strictly decreasing after the limit frequency.

It is advantageous to let the filter function be continuously derivable since this allows a digital filter having a smaller spatial extent and, thus, a more rapid filtration.

It goes without saying that the above features can be combined in the same embodiment.

In order to further illustrate the invention, detailed embodiments thereof will now be described, without the invention being considered to be restricted thereto.

Brief Description of the Drawings

Fig. 1 is a schematic view of a microscope according to an embodiment of the present invention.

Fig. 2 is a block diagram of the function of a microscope according to the invention.

Fig. 3 illustrates the filter function as a function of the frequency in a microscope according to the present invention.

Fig. 4 shows a digital filter according to the present invention.

Detailed Description of the Invention

Fig. 1 is a schematic view of a microscope according to the present invention. The microscope has a source of light 1, which illuminates an object 2 placed on an object holder 3. Light from the object is collected with a microscope objective 4. A digital image sensor is arranged at a distance from the microscope objective 4. According to this preferred embodiment, the digital image sensor is a CCD. The CCD 5, the microscope objective 4 and the object 2 are arranged in a spaced-apart relationship so that the image plane of the microscope objective coincides with the surface of the image sensor 5. The CCD is formed with a large number of sensor elements 6 which are mutually spaced apart a distance d . Each picture element corresponds to a pixel in a digital image. The image sensor 5 is connected to an image processing means 7, which in turn is connected to a display 8 and an input means in the form of a keyboard 9. In the image processing means, a first calculating means 24 and a second calculating means 25 are arranged. Between the microscope objective 4 and the CCD 5, lenses 10 are arranged to transfer the image to the CCD 5. The optical system consisting of the microscope objective 4 and the lenses 10 has a combined transfer function which describes how different spatial frequencies of the object 2 are transferred to the image plane. Depending on the design of the objective 4 and the lenses 10, spatial frequencies of

different degrees are transferred from the object 2. The maximum spatial frequency that is transferred from the object 2 to the CCD 5 is usually defined as the resolution of the optical system. Thus only structures corresponding to a certain minimum size of the object will be distinguished in the image. The size of the image, however, may vary by varying the mutual arrangement of the CCD 5, the microscope objective 4 and the object 2. The spatial frequency of the sensor elements is defined as the inverse of their double mutual distance $2d$. According to the invention, the object 2, the microscope objective 4, the lenses 10 and the CCD 5 are arranged so that the spatial frequency of the sensor elements is higher than the maximum spatial frequency of the image. The spatial frequency of the sensor elements is preferably 1.5 times higher than the maximum spatial frequency of the image and advantageously at least 2 times higher than the maximum spatial frequency of the image in order to obtain a reduction of noise.

When an object 2 is placed on the object holder 3, an image will be recorded by the image sensor 5. The recorded image is transferred to the image processing means 7, which processes the image before it is shown on the display 8. The image processing in the image processing means 7 is affected by parameters which are inputted via the keyboard 9.

Fig. 2 is a block diagram of the function of the image processing means 7. The recorded image from the CCD 5 is inputted at the top of the figure to block 12 and at the bottom of the figure to block 13. In block 13, a division into the colour components of the image is made, whereupon the divided image is transferred to block 14 for filtration by means of a digital filter. In block 12, a limit frequency (ω_0) is determined by the recorded image being transformed, whereupon ω_0 is calculated as the frequency below which 95% of the integrated signal in the transformed image is present. The calculation of ω_0

can be carried out each time a new picture is taken or when a user of the microscope initiates a determination of ω_0 .

According to the preferred embodiment, a digital filter is calculated when a user initiates such a calculation via the keyboard 9.

Fig. 3 shows a filter function as a function of the frequency which describes an amplification as a function of the frequency.

In block 15, parameters for the transfer function of the filter are fetched from the keyboard or from a memory 23 in the image processing means. Examples of the parameters that can be fetched from the keyboard 9 in block 15 are the amplification of the filter at the limit frequency, the position of the limit frequency and the appearance of the filter function above and below the limit frequency. In block 16, the transfer function 17 of the filter is determined on the basis of the parameters that are fetched into block 15. The filter function 17 is determined as follows:

$$H_f(\omega) = \begin{cases} e^{(\omega/\omega_0)^2 \alpha}, & \omega \leq \omega_0, \\ e^{\alpha \left(\frac{\omega_1^2 + \omega_0^2}{\omega_1^2 + \omega^2} \right) \gamma}, & \omega \geq \omega_0, \end{cases}$$

wherein α , γ and ω_1 are parameters which the user can modify in the input means 9. The parameter ω_0 can either be defined by the user or be determined automatically by the system and indicates the limit frequency. The amplification at the limit frequency is determined by α . γ and ω_1 determine how rapidly the filter fades away at high frequencies.

Thus, the filter function is two-dimensional and dependent on the sum of the frequency ω but independent of an angular parameter, a circular symmetrical function being obtained.

The filter function, however, may have a different appearance and can, for instance, be described by one

polynomial up to the limit value and another polynomial above the limit value. The filter function 17 has essentially the value 1 for the frequency zero and a peak value at the limit frequency (ω_0). After the limit frequency ω_0 , the function decreases. The filter function has, however, a value different from zero above a frequency exceeding the maximum spatial frequency of the image. The limit frequency essentially conforms to the maximum spatial frequency of the image. Once more with reference to Fig. 2, there is made in block 18 a two-dimensional inverse transform of the filter function which was calculated in block 16. The inverse-transformed filter function is digitised and cut off to a suitable size to constitute a digital filter for the recorded image. In block 14, the image of which the colours have been divided is filtered two-dimensionally by means of the digital filter. Subsequently, a voluntary grey-level transformation is made in block 19, whereupon the colours in the image are again put together in block 20. The grey-level transformation is carried out if there is a risk that the grey levels have reached outside permissible values in the filtration. After the processing of the image, the image is shown on the display 8 or stored in a storage means 26.

Fig. 4 illustrates an example of a digital filter 22 which is used in block 14. As is evident from Fig. 4, the filter is circular symmetrical around the top 21. When the image is filtered in block 14, the value in a pixel is multiplied by a value corresponding to the filter at the top 21 and added to the result of the multiplications between the adjoining pixels and a corresponding value in the filter.

A person skilled in the art realises that the invention is not limited to the embodiment shown and that many modifications are feasible within the scope of the invention. For example, block 12 in Fig. 2 can be omitted and the filter function be determined entirely by means of

parameters that are inputted via the keyboard 9 in Fig. 1. A person skilled in the art also realises that blocks 13 and 20 can be omitted if the image is not a colour image.

CLAIMS

1. A microscope comprising
an object holder (3),
optics which in an image plane form an image of an
object (2) which is placed in the object holder, and
5 a digital image sensor (5), which has a number of
sensor elements (6) for recording the image, c h a r -
a c t e r i s e d in that the image sensor and the image
plane are arranged in such manner that the spatial fre-
quency of the sensor elements (6) is higher than the
10 maximum spatial frequency of the image, the microscope
further comprising at least a first calculating means
(24) which is connected to the image sensor (5) and which
is adapted
to provide a two-dimensional filter function, which
15 essentially has a first value at the spatial frequency
zero, a second value which is different from zero at a
spatial frequency above the maximum spatial frequency of
the image and a peak value between the spatial frequency
zero and the spatial frequency of the second value,
20 to calculate a digital filter which corresponds to a
two-dimensional inverse Fourier transform of the filter
function, and
to filter a recorded image by means of the digital
filter.
- 25 2. A microscope as claimed in claim 1, c h a r -
a c t e r i s e d in that it also comprises an input
means (9) connected to the calculating means for input-
ting values which provide information about at least one
of the peak value of the filter function, the spatial
30 frequency of the peak value, the filter function for spa-
tial frequencies below the spatial frequency of the peak
value, or the filter function for spatial frequencies
above the spatial frequency of the peak value, the input-
ting means being connected to the calculating means and

the inputted values being used by the calculating means to provide the filter function.

3. A microscope as claimed in claim 1 or 2, characterised in that it also comprises a
5 second calculating means (25), which is connected to the image sensor and the first calculating means, and which is adapted

to Fourier transform the recorded image,
to determine a limit frequency below which the major
10 part of the light energy of the transformed image is to be found, and

to provide the first calculating means with the limit frequency as a value of the position of the peak value.

15 4. A microscope as claimed in claim 3, characterised in that the limit frequency is determined as the frequency below which at least 90% of the energy in the image is to be found.

5. A microscope as claimed in claim 1, 2 or 3,
20 characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

6. A microscope as claimed in claim 3 or 4,
25 characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the limit frequency.

7. A microscope as claimed in any one of the preceding claims, characterised in that the filter
30 function (17) is continuous and strictly growing from zero frequency to the position of the peak value and strictly increasing toward zero for increasing frequencies from the position of the peak value.

35 8. A microscope as claimed in any one of the preceding claims, characterised in that the filter

function is a convolution of two one-dimensional filter functions.

9. A microscope as claimed in any one of the preceding claims, characterised in that the filtered image is stored in a storage means (26).

10. A microscope as claimed in any one of the preceding claims, characterised in that it also comprises a display (8) on which the filtered image is shown.

11. A microscope as claimed in any one of the preceding claims, characterised in that the first calculating means is adapted to divide the recorded image into colour components, and

15 to provide a digital filter for each of the colour components.

12. A microscope as claimed in any one of the preceding claims, characterised in that the first value essentially is one.

13. A method for a microscope, characterised by the steps of

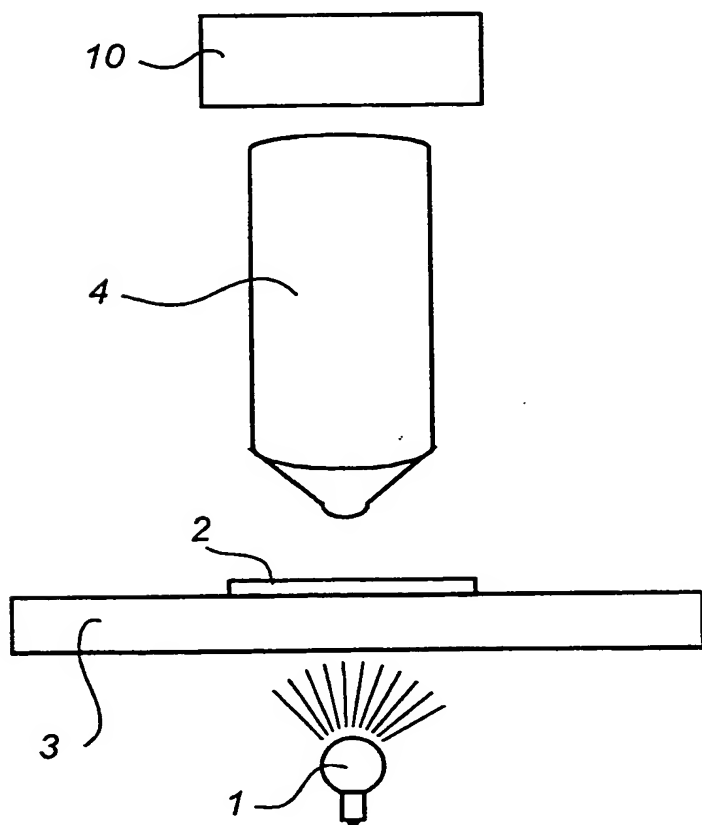
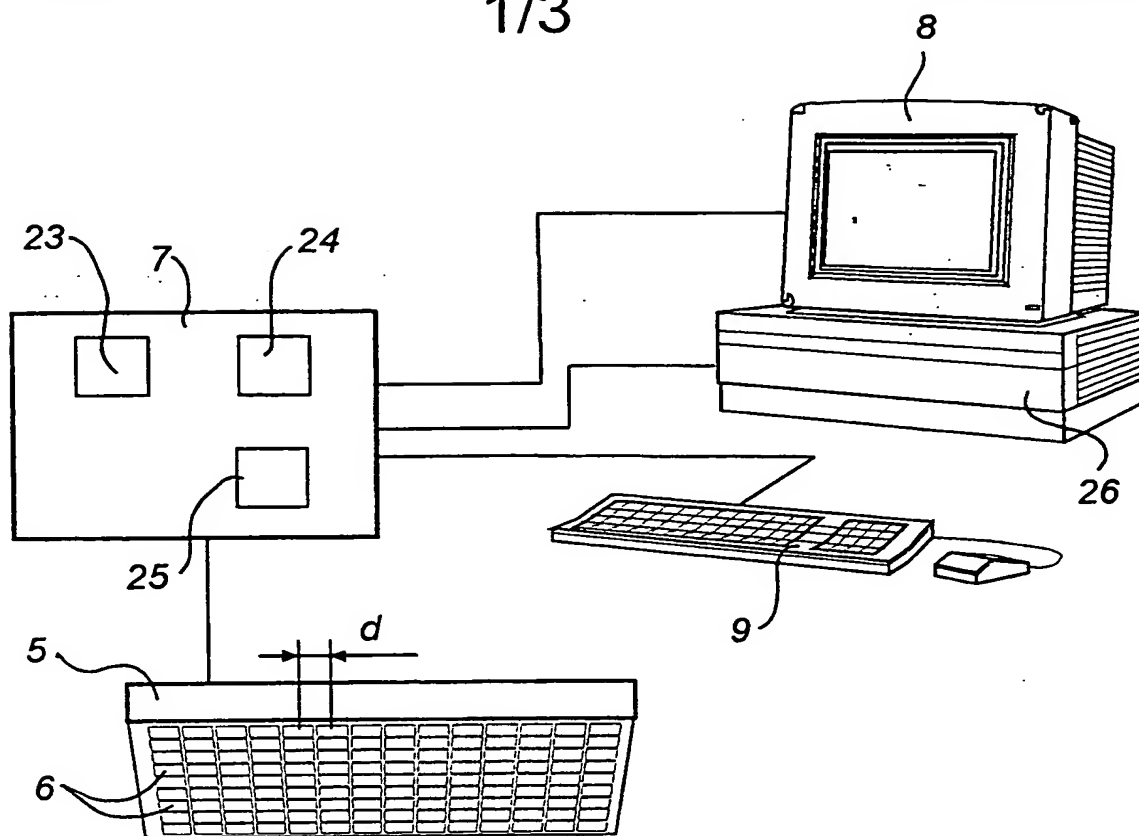
arranging an image sensor (5) which has a plurality of sensor elements (6), optics (4, 10) and an object (2) at a mutual distance from each other, so that an image of the object is formed on the image sensor (5), the spatial frequency of the sensor elements (6) being higher than the maximum spatial frequency of the image,

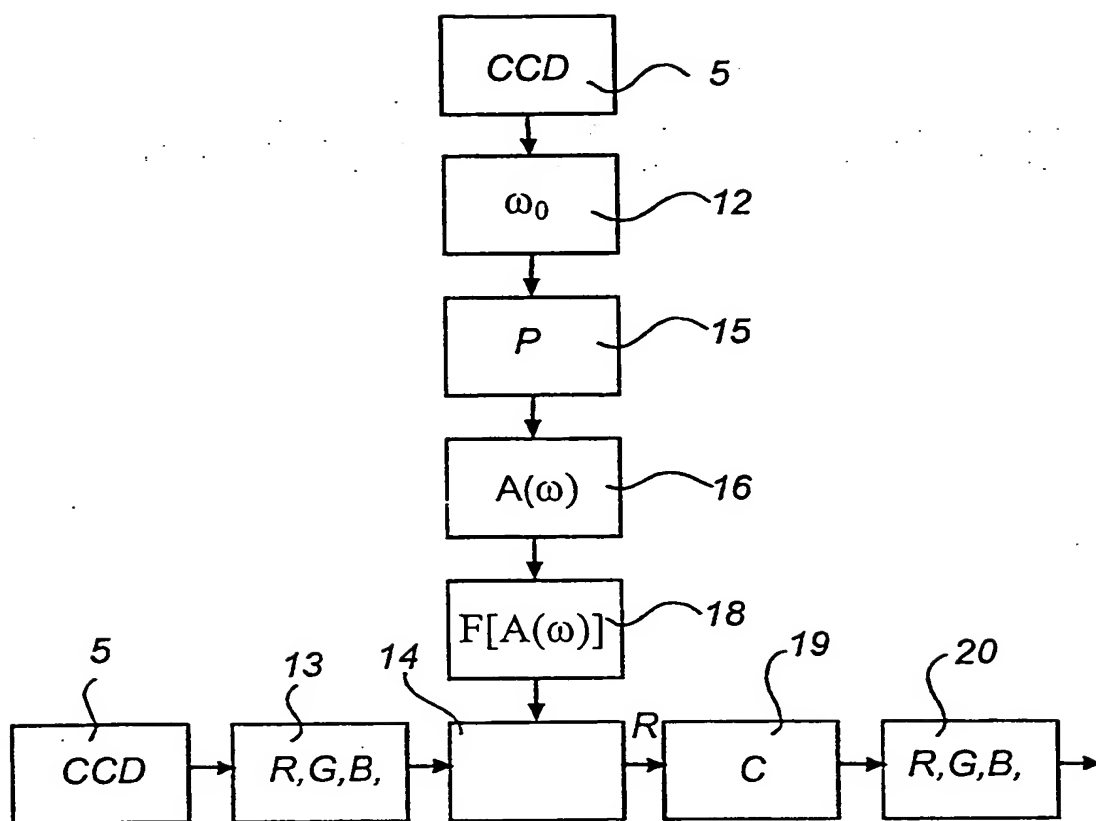
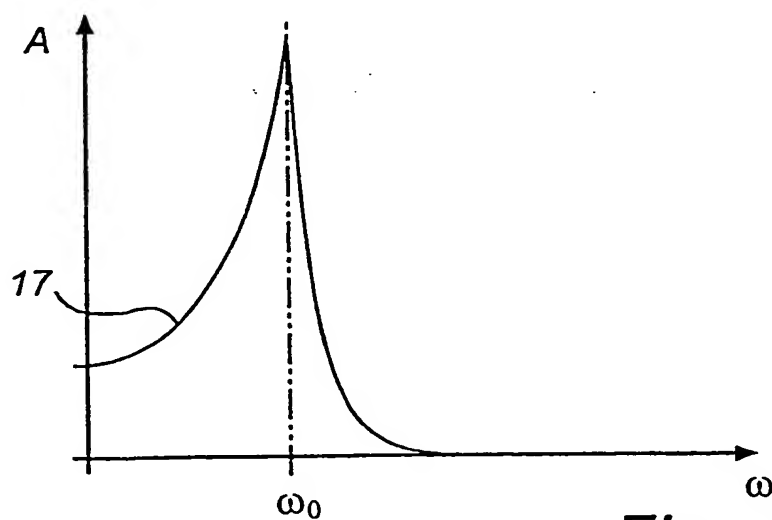
recording the image by means of the image sensor (5),

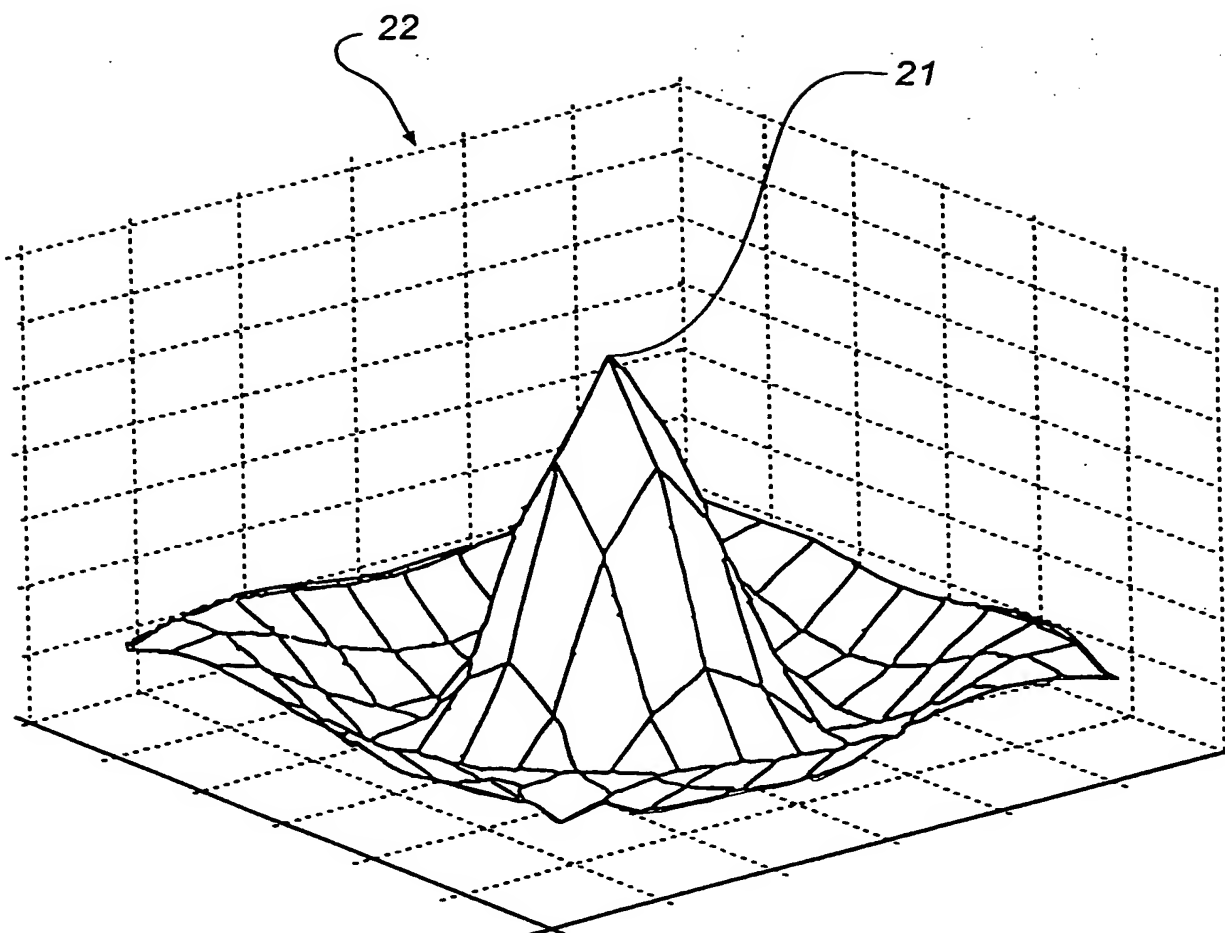
30 providing a two-dimensional filter function, which essentially has a first value at the spatial frequency zero, a second value different from zero at a spatial frequency which is higher than the maximum spatial frequency of the image and a peak value between the spatial frequency zero and the spatial frequency of the second value,

calculating a digital filter which corresponds to a two-dimensional inverse Fourier transform of the filter function, and

filtering the recorded image by means of the digital
5 filter.

*Fig. 1*

*Fig. 2**Fig. 3*

*Fig. 4*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01376

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G02B 21/00, G02B 21/36, G06T 5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G06T, G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| D,A | US 5696850 A (K.A. PARULSKI ET AL.), 9 December 1997 (09.12.97) -- | 1-13 |
| A | Digital Image Processing, pages 189-201, R.F. Gonzales, R.E. Woods Addison-Wesley Publishing Company, Inc. 1992 ISBN: 0-201-60078-1 -- ----- | 1-13 |

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

25 October 2000

Date of mailing of the international search report

02 - 2000

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INTERNATIONAL SEARCH REPORT
Information on patent family members

03/10/00

International application No.
PCT/SE 00/01376

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